ESTIMATING THE TOTAL VOLUME OF RUNNING WATER BODY: A CASE STUDY OF PESHAWAR BASIN, PAKISTAN

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DEDICATION

This thesis is dedicated to my parents. I would like to thank my beautiful parents **Mr. & Mrs. Dr. Umar Said** who always believed in me, supported me and motivated me at my hard times throughout my life. My lovely sisters and brothers, a single glance upon them makes me relax and joyous. And it was never possible to achieve this success without their unconditional love and prayers. I would lastly like to thank my dear friends, for their support and encouragement.

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ABSTRACT

The main purpose of this study is to estimate the changes in land use and land cover in the Peshwar Basin, Pakistan (2000-2020). With the help of advanced geographic information systems (GIS), land use and topographic changes were identified. Moreover, some remedial measures were taken to develop land use/cover of the area to overcome the future problem. This will greatly improve the selection of areas designated as the agricultural, industrial, and/or urban sectors of the region. Land use around the Peshawar basin (Peshawar, Madan, Charsadda, Swabi and Nowshera) has changed every day with the addition of new developments (agriculture, trade, industry, cities). The rationale of this study was to evaluate land use/cover changes in the Peshawar basin from 2000 to 2020. The temporal and spatial dynamic measurement of land use/cover change uses two satellite images, classifies them through a supervised classification algorithm, and finally applies post-classification technology to detect changes in GIS. This study investigated the land cover changes in four categories, which were built-up Area, Agriculture Land, Rang land, and water body, by using Maximum Likelihood Classification (MLC). It is inferred that the built-up area was increased the most in the last ten years i.e. 2010 to 2020 as compared to other classes. Results show that, from 2000 to 2020, there is a significant increase of 16.48% in urbanization and a decrease of 10.46% in vegetation. These results can be useful for future planning and development.

Groundwater depletion is an emerging problem is worldwide due to climate changes and the rapid increase in urbanization. GIS application makes it possible to estimate the total potential of running and groundwater by determining the appropriate locations. The objective of the current study is to estimate the total volume of running water by applying GIS in the Peshawar basin situated at the southern foothills of the Himalaya of Khyber Pakhtunkhwa, Pakistan.

The basin is filled with quaternary sediments ranging from Pleistocene to recent in age. However, the sediments of the central part of the basin contain a relatively large portion of fine material and are characterized as lacustrine sediment. Based on the data of the 20 years from (2000 to 2020), the total runoff volume in the Peshawar basin in (2000-2010) is 13.9 cubic km. In comparison, the total runoff volume in the Peshawar basin from

(2010-2020) is 19.4 cubic km. The volume of water is estimated for the settled/covered areas. This volume estimation will assist in quantifying the total infiltration rate. The total study area of the current research work was 7,176 km^2.

Furthermore, Peshawar Basin is covered mostly by vegetation, which increases the chance of precipitation infiltration. However, in settled areas where vegetation is not present, the infiltration rate is very low. Therefore, the present case study of the Peshawar basin will help farmer community and environmentalists to manage rang land, agricultural land, populations, and water body. Most significantly, the current study will help manage floods that occur every year in Peshawar, Pakistan. Finally, we proposed the prospective applications of GIS in integration with AI (Artificial Intelligence) as a future work opportunity.

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ABBREVIATIONS

SPI = Standard Precipitation Index

WAPDA = Water and Power Development Authorities

GIS = Geographical Information System

C.I.P = Coefficient of Infiltration Potential

C.I.P.S = Coefficient of infiltration potential weighted with the slope

P.E.T = Potential Evapotranspiration

E.R.S = Electrical Resistivity Survey

D.C.E.R = Direct Current Electrical Resistivity

VES = Vertical Electrical Sounding

G.P. S= Gallons per Second

CHAPTER 1

INTRODUCTION

1.1 General Statement

The Peshawar Basin is located in the southern foothills of the Himalayas between Khyber Pakhtunkhwa latitude 32°N-37N and 70°E-74E east longitude. The major city of the basin is Peshawar, Madan, Charsadda, Swabi and Nowshera. The east and west-flowing of Kabul River ranging from and its tributaries irrigate the basin and join the Indus at the eastern exit. Peshawar basin is surrounded by mountain ranges of Khyber in the west and north, Attock-cherat in the south, and Swat in the northeast. The basin is filled Paleozoic sequence of sedimentary rock is exposed in the range fringing the Peshawar basin (Naqvi et al., 1998).

The Peshawar Basin is located in the mountains at the southern margin of the Pakistan Himalaya. The volume estimation in the Peshawar basin will assist in quantifying the total infiltration rate. The total study area of the current research work was 7176 km^2. The average running water body volume in the Peshawar basin an average is 13.9 and 19.4 Cubic Kilometer, which is quite high because of its stratigraphy.

Therefore, the present case study of the Peshawar basin will help farmer community and environmentalists to manage barren land, agricultural land, range land, Built-up area, and water body (Chitrali et al., 2012).

Administratively the Peshawar Basin was divided into five districts (Statistic Bureau of Pakistan).

i. District Peshawar,
ii. District Swabi
iii. District Madan
iv. District Charsadda,
v. District Nowshera

Most of the fresh water on the earth is stored underground. When it is not raining, the reservoir is the most important source of water (Morris et al., 2003). Groundwater in an area saturated with soil and geographical composition. More than 30% of the world's population is directly on the reservoir for drinking water (Connor et al., 2015). Human activities affect surface water, and water scarcity depends on groundwater resources in many cities around the world. The water quality of groundwater is stable, and the amount of fresh water is very large compared to the reserve. The development of surface water reservoirs can be continued for economic growth provides a reliable water supply for industrial, agricultural, and domestic use. Water is one of the most crucial elements in this universe and the vital component for all living things and especially for human life (Shah et al., 2000). The subsurface potable water layers should be identified appropriately and should be prevented from any possible contamination. Geographical Information System (GIS) plays a significant role in modeling and identification of optimum locations for water garnering or recharging structures. Similarly, GIS software can be used for hydrological modeling as well as for estimating underground and running water with bulky three-dimensional and attribute data. Earlier research studies have been published by applying GIS and remote sensing for rainwater running, collecting, and storage. Performing experiments and case studies needs digital datasets in the form of satellite images and textual data. These data are collected from various sources such as topography, hydrology, vegetation, soil, and meteorology. Rainwater flows and drains in a specific area via a surface channel after nourishing the surface and sub-surface losses. Rainwater in arid and semi-arid regions acts as a water source for various purposes once the auxiliary sources such as wells, springs, and streamflow water dry up (Ślesicki et al., 2009).

The potential of groundwater with the ideal to average quality (Ashraf et al., 2009). conducted a study to investigate the potential of artesian aquifers in the arid mountainous regions of DI Khan, Pakistan. They employed the GIS as an integrated tool to examine the potential of groundwater and picture the spatial data in two dimensions and three dimensions (2D and 3D). Subsurface lithology, stratigraphic data, and primary database of the aquifers have been recorded through the survey and observations. Various underground profile layers focused on examining the underground conditions of the study area employing Rockwork, the GIS integrated software. They discovered the extractable quantity of about 1700 MCM of water potential was available in the study area. Using geoprocessing techniques for lithological modeling identified three different aquifers based on subsurface stratigraphic information. Two aquifers were discovered semi-confined to confine with a depth of about 200 m. Confined aquifer-1 was found at a depth of 118–113 m, aquifer-2 was discovered at a depth of 182–195 m (Chowdhury et al., 2010) investigated the groundwater potential using RS/GIS and GPS ground trotting techniques in West Bengal, India. Using IRS-ID imagery, they delineated the thematic layers of lithology, land use, drainage, recharge, soil, slope, and water bodies and assigned weight on each thematic layer. The study discovered three types of groundwater potential zones categorized as good (15%), moderate (55%), and poor (30%) of the total study area.

The ability of GIS to process large amounts of spatial and attribute data makes GIS an important tool for hydrological modeling. Certain functions (such as map overlay and analysis) can extract and add hydrological parameters from various sources (such as soil, land cover, and precipitation data) (D. Winnar et al., 2007).LULC mapping of the river basin is a useful tool that can be used for good planning and management of urbanization, agricultural practices, and other human activities (Gregrio et al., 2012).

1.2 Study Area

Peshawar basin is situated at the southern foothills of Himalaya between latitudes 32°N–37°N and longitudes 70°E–74°E of Khyber Pakhtunkhwa province in Pakistan. Within Khyber Pakhtunkhwa, the major districts of the Peshawar basin are Peshawar, Mardan, Charsadda, Swabi and Nowshera. Peshawar basin is surrounded by the mountain ranges of Khyber from the west and north, Attock-Cherat in the south and Swat in the east and northeast.

Peshawar mountain basin lies at the south margin of the Pakistan Himalaya. It is confined in the south by the Atttock-Cherat boundary, and towards east and west through Gandghar and Khyber boundaries respectively. Towards the north and northwest sides, the Peshawar basin is comprised of strata that meet sediments intervened by the “granitic rocks belonging to the marginal mass of the Indian plate”.

GIS is one of the most important software tools for hydrological modeling due to its potential to leverage the huge quantity of spatial and attribute data. Its features, like map overlay and analysis support, helps in deriving and aggregating the hydrologic parameters from diverse sources like; soil, land cover, and rainfall data. Land Use and Land Cover (LULC) mapping is also a useful tool that can be used for good planning and management of urbanization, agricultural practices, and other human activities

1.3 Problem Statement

Pakistan is facing its worst water crisis in recent years. Currently, the amount of water available in Pakistan has fallen from 5,000 cubic meters per capita to 1,100 cubic meters per capita in the past 50 years. It is expected to be reduced to 700 cubic meters per capita by 2025 (Kahlon et al., 2003). The main source of water in the Peshawar Basin is groundwater, which leads to a shortage of water in the densely populated basin. The project area includes Khyber Pakhtunkhwa province and major urban centers, where the migration of rural people has increased water pressure. Due to rapid population growth and unplanned industrial development, insufficient groundwater resources have been abused. Seasonal water shortages and low groundwater levels increase pumping and electricity costs. Untreated wastewater from this river flows into the Kabul River, and excessive pumping will release more water from the Kabul River. Aquifer.

Groundwater research began in the early 1960s when there were stagnant water problems in Mardan, Chalsada and Peshawar near the Kabul River. The Water and Energy Development Agency (WAPDA) introduced the Salinity Control & Reclamation Project (SCARP) to fundamentally solve this problem.WAPDA (1963) reported in detail about the Sherkera tube well irrigation project about 30 kilometers away from Peshawar. This detailed underground report included five holes, two of which were converted into tube wells for pumping tests. The reason for paying attention to the Mardan area is because of the salinity problem near the Kabul River and the launch of SCARP to solve it. In arid climates, groundwater becomes unbalanced due to excessive evaporation. (Lubczynski et al., 2000). Due to the dryness of the area, the high rate of groundwater resources development, and the lack of surface water for domestic and industrial use, the lack of fresh saltwater and groundwater is a major problem in Karachi (Mashiatullah et al., 2002).

This research is also important in the context of the Peshawar Basin, where the problem of salinity persists in the Peshwar basins of the Peshawar area. Sajjad (1983b) reported a synthesis of more concentrated data on the right bank of the Kabul River. The author compiled the WAPDA report, previous work by Malik and Kazmi, and some unpublished data. The report contains useful information about pumping test results, well records, and water quality. Bleomendaal and Sadiq (1985) produced a comprehensive report on the Mira region and Mardan and Peshawar regions. Technically, the report discusses groundwater resources, with special attention to the Mira area. This report discusses the WAPDA/TNO-DGV survey from 1983 to 1985. In the report, 14 boreholes were tested, several aquifers were tested, resistance measurements and water budget calculations were performed.

These reports are generic and can help you understand the area and its related geography. Robberts (1988) wrote a comprehensive report on the hydrology of Peshawar. The report is a desktop study, collecting various technical reports from previous investigations. The report contains valuable information about groundwater resources and development in the Peshawar area. Krusemen and Naqvi (1988) wrote a comprehensive book that compiled previous reports on groundwater exploration projects in Khyber Pakhtunkhwa. This book contains general information about Khyber Pakhtunkhwa (KP) province, as well as local groundwater surveys conducted by various departments and authors. A detailed description of the hydrology of the mountain basins in the Peshawar and Mardan regions. The total charge and discharge count for the entire valley of Peshawar. This book is written in a language suitable for planners, managers, and groundwater professionals. The hydrology of Peshawar will be discussed and explained using chapters and tables. The creation of the contour heading creates conditions for exploring the future potential of groundwater resources. Bundschuh (1992) conducted a comprehensive survey of groundwater resources in the Peshawar Valley. The survey was completed within 3 months, and the main purpose was to classify groundwater suitable for agricultural water and drinking water. The Peshawar Valley is divided into Peshawar, Sawabi, Nowshera, Karlang, and Mardan regions, covering an area of approximately 8,000 square kilometers. According to the author's research results, the depth of the groundwater level in the valley area is less than 5 m. Except for the mountainous and southern regions, the groundwater level can reach 10-30 m. If the direction of groundwater flow points to the center of the catchment area, the conductivity of the slope is less than 800 µS/cm. However, it is reported that the center is as high as 8000 µS/cm . The author also provided and analyzed water samples from the Piper chart. Asim (2005) conducted a study of the Peshwar valley total area is approximately 5,500 square kilometers. He used FEMWATER (a finite element flow and transfer model) to establish a numerical model of the watershed. The deep and shallow wells on the south side of the basin are more open and the water flow is rapid. Nasreen (2006) conducted a detailed study on the soil, surface water, and groundwater in the Peshawar Basin. The main goal of this research is to study the physical and chemical parameters of water and soil to monitor the environmental degradation of the Peshawar Basin. Physical parameters such as pH, conductivity, temperature and total dissolved solids were studied.

They carried out a hydrophysical investigation at the Nowshera area situated at the southeastern side of the Peshawar District. The authors used 30 vertical electrical points (VEP) and made the resistivity profile map with the pumping test data. The data showed consistency with the borehole data. They argued that the area consists of alluvium deposits with alternate clay, silty clay, coarse sand, and gravel. High resistivity values were correlated with the coarser sediments, and the lower values were related to the fine materials. The studies carried out are supposed to be important study because they could be helpful in the identification of the hydrogeological units of the Peshawar District basin. In 2017, the Urban Policy Unit Planning Development (UPU, 2017) released a comprehensive report on land use planning from 2018 to 2037. The report emphasizes groundwater management under extreme pressure. The population and land use distribution of the area are highlighted in detail. Groundwater reclamation between rivers and uneven waterways continues to increase, affecting agricultural capacity. The total area of Peshawar District is 336 square kilometers, accounting for 27% of the total area. The Salinity Control and Reclamation Project (SCARP) was launched from 1980 to 1997. The SCARP team installed 200 wells and pumped water to create a vertical discharge. According to reports, the vertical drainage training was unsuccessful because the water level did not drop.

The groundwater storage rate in Peshawar is directly related to population growth and rapid urbanization (Adnan et al., 2014). The annual precipitation is very low. The amount of groundwater infiltration in ditches and irrigation depends on the flow of the Kabul and Barra rivers, which fluctuates with the consumption of the upstream catchment area. Worryingly, 95% of the population depends on water wells for drinking water and other households. With the construction of insoluble aquifers (concrete structures) in urban areas, increased and uncontrolled pumping rates will increase the pressure on groundwater. Private and public industries that rely on the water are also responsible for water shortages. These include marble factories, paper mills, petroleum industries and bus stations. With the development of these industries, more and more water is extracted from the land, and the depletion of groundwater in the vicinity of these areas is worrying (Mansoor Ali et al., 2007). Previous studies on groundwater in Peshawar focused more on water quality. However, no reservoir assessment investigates the response to amniotic fluid in all areas. Therefore, it seems necessary to study the impact of pumping on groundwater resources. Therefore, it is necessary to develop a reasonable groundwater model to provide a comprehensive method for predicting the effect of water absorption. The focus of this study is to use groundwater models to evaluate and optimize the groundwater resources in the Peshawar Basin to understand and improve the flow patterns of abstraction and recharge.

The idea of the project was to estimate the total volume of water that is contributing to the Indus River. However, to measure the total volume, a comprehensive range coverage of Peshawar basin by rainfall gauge station. Another problem is it is difficult to measure the volume of running water because of heavy vegetation.

The softcover of vegetation provides an ideal situation for infiltration. However, the rate of infiltration for settle (covered area) is different. If we assumed that most of the rainfall which is received by this settle/cover area would hardly penetrate or be lost, most of this water becomes running water. If we find out the total area covered by settlement within basin boundaries, this area, along with rainfall data, would help us in quantifying the total volume of running water if we assumed the running water from the settlement area is the actual contribution to the Kabul River which finally contributed to Indus at Attock. Using Meteorological data and ArcGIS software application. The research objectives are as follows:

1) To estimate the recharge of the area.
2) To calculate the LULC of Peshawar Basin.
3) To calculate the total runoff water volume in the Peshawar basin.

1.4 Methodology for Volume of Running Water Body

The study area location is shown in Figures 1.1. As shown in Figure 1.1, the total volume of water was calculated by using the GIS for the selected locations in the current study area. The output data from the GIS modeling were then analyzed using specific software tools, and finally, the results for the volume of water in the study area were presented. In order to study the LULC changes in the Peshawar Basin, two multispectral satellite images of the basin were acquired in two periods. 2010, 2020. Moran in 2004 compared post-classification comparison with principal components analysis (PCA) used for change detection to monitor changes in

LULC by making use of remotely sensed data for instance image differencing. post-classification comparison was found to be the most accurate procedure by variety of studies as it offered an advantage of representation of nature of occurring changes (Moran et al., 2004).

Post classification in urban environment has been effectively used by various researchers due to its efficiency in detecting the location, nature and rate of change (Hardin et al., 2007). The land cover changes were investigated into four categories, which were built-up Area, Agriculture Land, Rang land, and water body, by using Maximum Likelihood Classification (MLC). MLC is the most widely used method. Among them, MLC is considered the most accurate classification method (Goldberget et al., 2007). The temporal and spatial dynamic measurement of land use/cover change uses two satellite images, classifies them through a supervised classification algorithm, and finally applies post-classification technology to detect changes in GIS.

The volume of running water can be calculated using equation (1):

The volume of water = settlement land area * rainfall precipitation (1)

- The Settlement area of the Peshawar basin is 2943.867 & 4135.805 km^2.
- The total sum of rainfall precipitation of Peshawar from (2000 – 2020) is 4740 mm and 4704 mm.

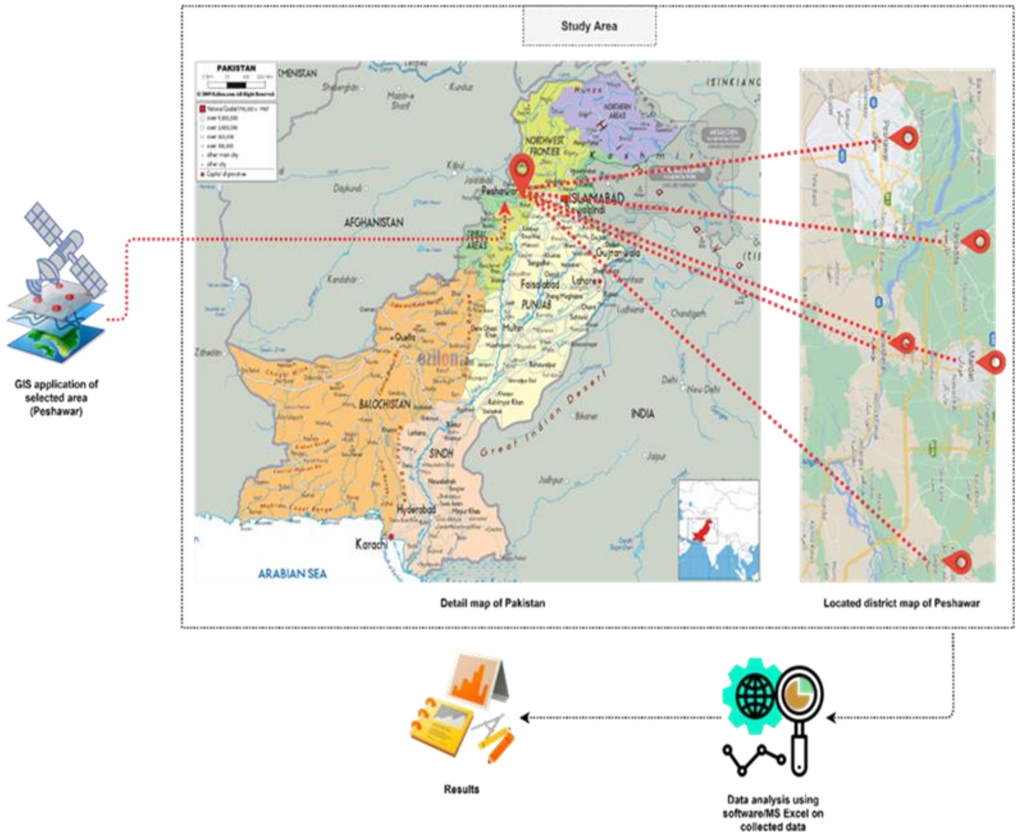

Figure 1.1: Proposed methodology in the groundwater modeling process

Chapter 2

General Geology and Stratigraphy

2.1 Geology and Tectonics

Peshawar basin is surrounded by mountain ranges. At north MMT (Lower Swat and Malakand ranges), At south Attock- cheat ranges, At west Khyber ranges, At east Gandghar ranges. Peshawar basin is an intermountain basin and fundamental part of the Himalayan Continental collision zone, located at the southern edge of the Himalayan and northwest of the Indus plain. It was created during Paleocene to Pleistocene time throughout the uplifting of the Attock-Cherat Range (Burbank et al., 1985). It is boarded by mountain ranges of Khyber in the west and northwest, Attock-Cherat in the south and Swat in the northeast, while its southern and eastern side is by the Indus River. The Khyber Mountains are the eastern edge of the Sulaiman Range (Chaudhary et al., 1980). The Attock-Cherat ranges mark the southern margin of the basin and are subjugated by the metasediments of the Precambrian to Devonian age. Further to the south, it is trusted over by the folded strata of the Kala-Chitta Range (Tahirkheli, 1980). The lower Swat Buner Schistose group and Swat Granitic Gneisses surrounded the Peshawar Basin northeast (Martin et al., 1962). These rocks are considered to be the base of the Stratigraphic sequence of the basin (Kazmi et al., 1984). The southern slopes of these rocks cover the Malakand Mountain range and stretch eastwards into the lower Swat-Buner area.

late Paleozoic comprises the greenschist and facies Meta basalt, politic and prismatic schist and calc silicates (Chudhary et al., 1976). The topographic expression is marked by gentle and moderate escarpment slopes. In the vicinity of the basin, the litho-stratigraphic sequence of the Khyber Mountain range comprises metasediments and low-grade metamorphic rocks with minor intrusions (Shah et al., 1980).

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Along the Kabul River, various escarpments could be seen which are predominantly composed of alluvial fan deposits and in addition to that sand, silt and clay which are bedded horizontally are present throughout the Peshawar basin (Cornwell, 1998). The southeastern part of Peshawar extending to the Nowshera area has been studied in detail by Muhammad and Khalid (2017). This area studied is the part of the Peshawar basin which covers the central flood area near the Kabul River and is considered gravel sand sediments belonging to an alluvial fan environment. The sediments have been transported by the weathering and erosional process suggesting a low degree of sorting in the sediments and ranging composition of the sand, gravels, and pebbles interconnected with clays and other fine materials (Mohammad and Khalid, 2017).

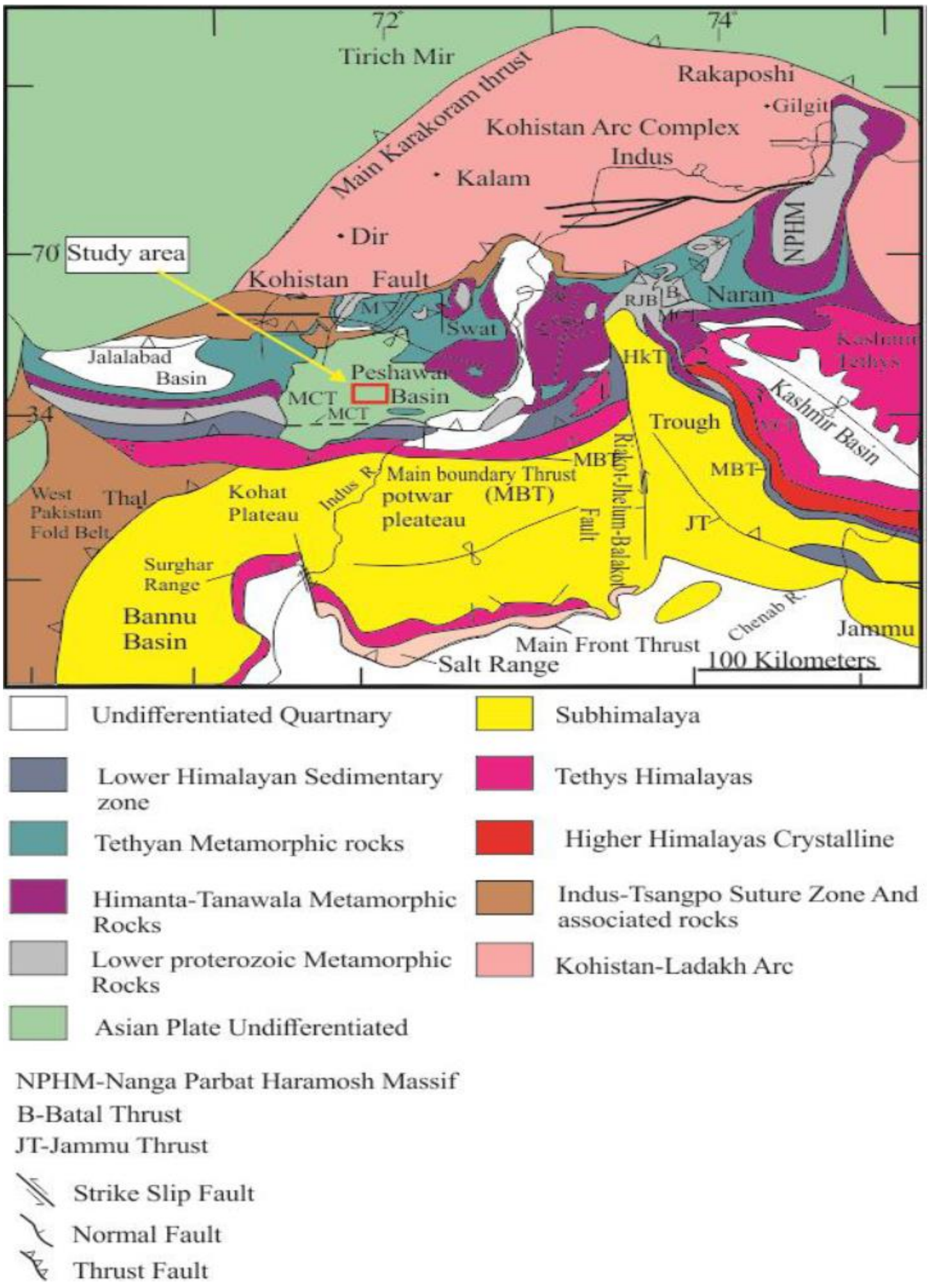

Figure 2.1:Tectonic map of the NW Himalayas. The red rectangle in the map represents the study area (Magsi et al., 2015).

2.2 Stratigraphy of the area

The study is divided into four units. The oldest rock is the Landikotal slates, which is covered with shagai limestone covered by the Ali Masjid stratum, and the last and highest stratum is Khyber limestone (Shah et al., 1970)

(Fig. 2.2). Earlier workers had given ages to these four units ranging from Ordovician to Permian age.

From younger to oldest the stratigraphy is as followed.

Khyber Limestone

Ali Masjid Formation

Shagai Limestone

Landikotal Formation.

2.2.1. Landikotal Formation

The detailed analysis of this unit was given by Stauffer (1968) and proposed as "Landikotal Slates" since a thick succession is exposed at Landikotal town. The formation is an accumulation of limestone, slates, phyllite, and quartzite in dolomite intruded by basic rocks (Shah, 2009). Shah (1969) It is suggested that almost the entire unit will be a Landikotal formation. The composition is mainly gray-green to yellow-gray phyllite and slates. Lists are useful in some places. According to the type of area, the strong contact with Khyber limestone is wrong, and the formation of Shagai limestone and Ali Masjid was not seen. The formation has been assigned Ordovician to Silurian age (Shah et al., 1969).

2.2.2. Shagai Formation

Stauffer (1968) Shagai Limestone is named after Shagai Fort on the Khyber Pass highway. The main limestone is large bedded micritic limestone. At the Missri Khel area, the lower contact of the Shagai Formation is confirmable with Landikotal formation and upper contact with Ali Masjid Formation. The Shagai unit is connected to Landicotal studs in the Khyber Pass area. The lower parts are 5m limestone, light gray-brown, thin layer, medium to fine, decorated with countless calcite veins, newly decorated recrystallized; totally recrystallized is a dolomitic overlaying this unit is 16-meter dolomitic limestone of light brown color. The topmost unit of Shagai Formation is dolomitic limestone thick-bedded and massive fine to medium-grained highly fractured ferruginous chartferious with nodules on the surface with calcite veins (Shah, 2009). Shah et al (1980) assigned Silurian to the early Devonian age and collated the formation with Inzai Formation (Attock-Cherat Ranges) and Nowshera Formation, respectively.

2.2.3. Ali Masjid Formation

The Ali Masjid is named after Stauffer (1968) because it is located on the Kyber highway. The species categories proposed by Stauffer (1968), Shah (1969) are selected from the northeastern part of Kyber Pass. It is now recommended to treat sections of the Kyber Expressway as the main reference section rather than the section type. The Ali Masjid unit consists of sandstone at the lower portion with the presence of siltstone, quartzite, and volcanic ash and conglomeritic beds at the different stratigraphic levels in the unit. The lower part of the unit is slightly calcareous. At about 24-meter-thick, a 4.5-meter-thick conglomeritic bed lies at the top of the unit. Ali Masjid village at Khyber Pass is assigned as its type of locality (shah et al. 1980) along the northeastern part of Khyber Pass.

At Khyber Pass, the formation is faulted that why its thickness is uncertain. At Khyber Pass Highway, the section has no fossils, whereas fossils are discovered along the Missri Khel and Makhshwani sections (Shah, 2009).

2.2.4. Khyber Limestone

The previous name, a thick "Limestone unit," was given by Griesbach (1892) and Hidden (1898). Stauffer (1968) gave the name Khyber Limestone to this formation. The formation predominantly comprises limestone that grades into marble and dolomite, with minor argillaceous and arenaceous partings (Shah et al., 1980). Limestone is a thick layer of medium to fine grains, completely recrystallized. Gray provides a new surface, while the weathered surface has shades of gray and yellow. Dolomite is gray, fine-grained and medium-thick. Marble is connected to limestone, and there is a layer of marble up to 30 meters deep. To the north of the Kyber Pass section, the basic diorite dykes and sills with a thickness of 5-6 meters. These dykes and sills are found at the top of the formation and are considered to be smaller than the Khyber Pass area. The eastern limestone unit of Kyber contains no fossils and is located near the Kyber Pass village of the Ali Mosque. No fossils are reported from the Khyber Limestone unit exposed at the Khyber Pass area. In contrast, along the Gandah Galla Mountains, the limestone unit is highly fossiliferous, containing several species of products and foraminifera (Shah, 2009). In the type of locality, Khyber Limestone attained a maximum thickness of about 1000 meters with several highly fossiliferous beds, hence correlated with the Nowshera Formation of Devonian age (Shah et al., 1980).

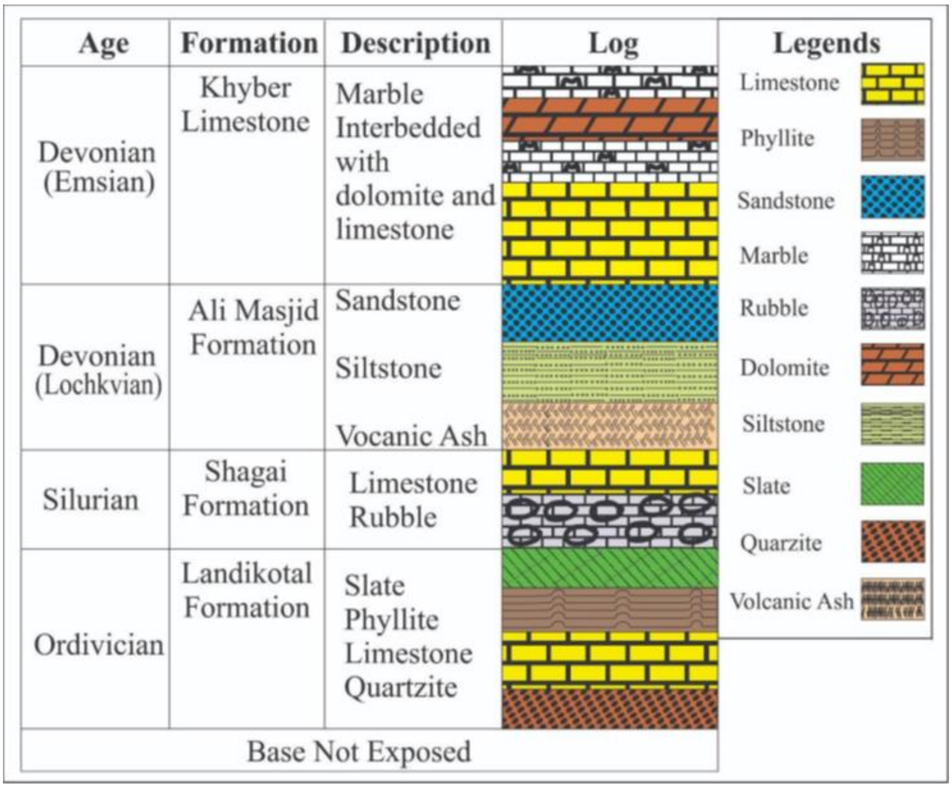

Figure 2.2: Stratigraphic column of the study area was adopted from (Khan et al., 1989).

2.3 River in Peshawar basin

Mainly three rivers cross the Peshawar basin.

2.3.1 Kabul River:

It is 700 km long emerges in Mardan Wardak province in the sanglak range of the Hindu Kush Mountains in Afghanistan. Its elevation is 2,400 meter and its meet with Indus River at Attock, Punjab, Pakistan (Nizami et al., 1973).

2.3.2 Swat River:

It is located in the northern region of Khyber-Pakhtunkhwa province. Pakistan. Hindu Kush Mountains are the source of the Swat River. And 240 km long (Nizami et al., 1973) .

2.3.3 Indus River:

It is one of the longest rivers in Asia. It flows over China, India, and Pakistan. The location where the Indus River start is the Tibetan plateau. Its elevation is 4,255 meters, and its length is 2,880 km (Nizami et al., 1973).

Indus Rivers meet with the Kabul River near Attock and flow some 30 km north of the Khyber Pass, Nowshera. This river has the great rule in recharge of Peshawar basin. (Nizami et al., 1973).

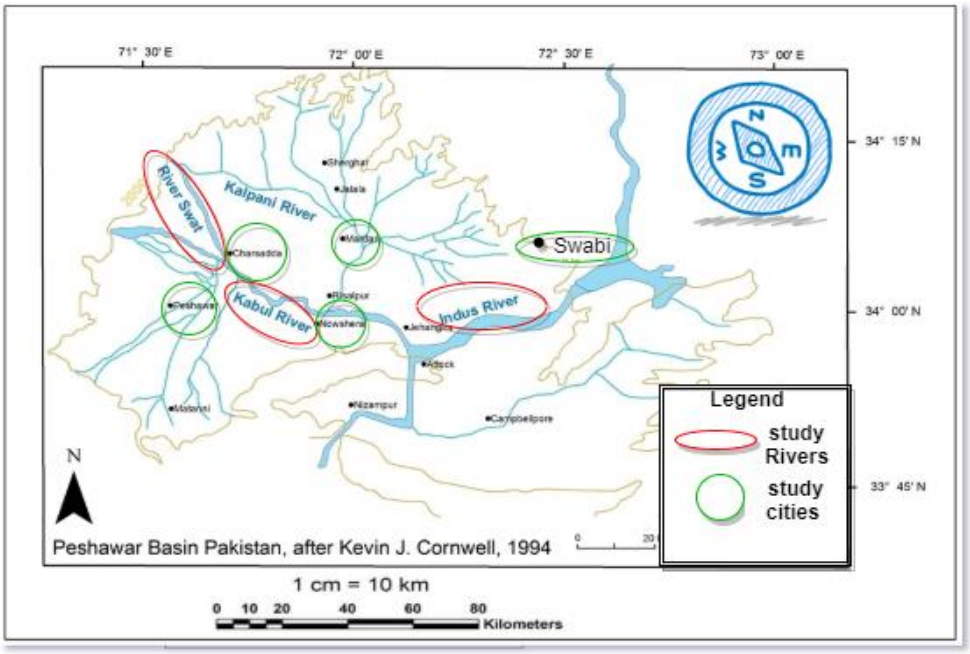

Figure 2.3:River in Peshawar basin (kevin et al., 1994)

CHAPTER 3

RESULTS

3.1 Introduction

The rainfall precipitation data is taken from the Regional Meteorological Department of Peshawar from 2000 to 2020. ArcGIS 10.7 software 2019 version was used for generating, handling, and production of various district maps in the current study. Microsoft Excel sheets were used to analyze and develop mathematical computations for running water estimates with precise weights.

In order to study the LULC changes in the Peshwar Basin, two multispectral satellite images of the basin were acquired in two periods. 2010, 2020. The 2010 and 2020 (LANDSAT) images were taken from the Earth Science and SUPARCO data interfaces of the United States Geological Survey (USGS), respectively.

The rainfall precipitation graph for the Peshawar region for 2000 to 2020 is given in (Figure 3.1&3.2). It can be seen that the volume of rainfall in the Peshawar region is more during the year (2001, 2006, 2013 & 2017). The total rainfall precipitation is equal to 5551 mm and 4704 mm.

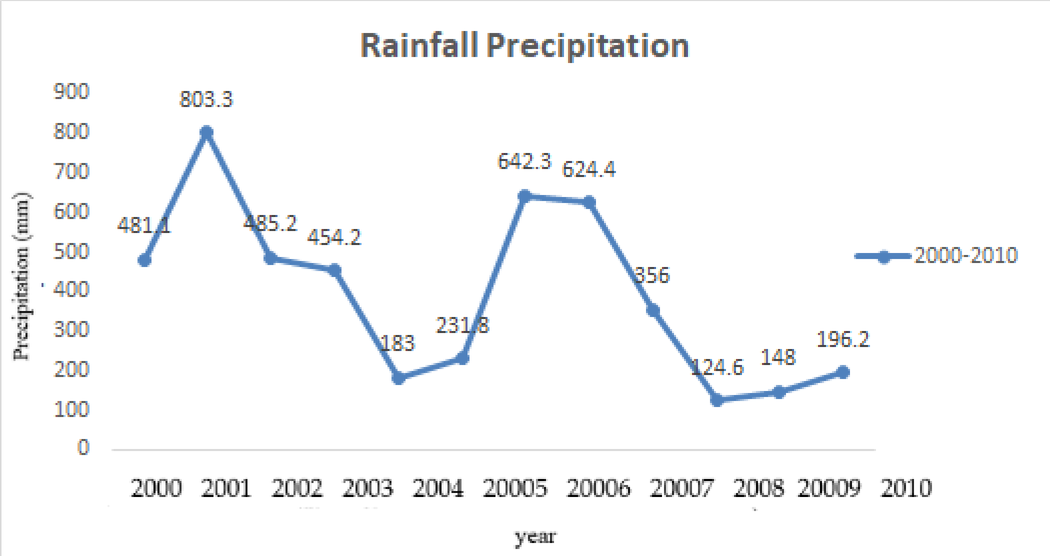

Figure 3.1: The rainfall precipitation in Peshawar basin from (2000-2010) Total precipitation is equal to 4740 mm.

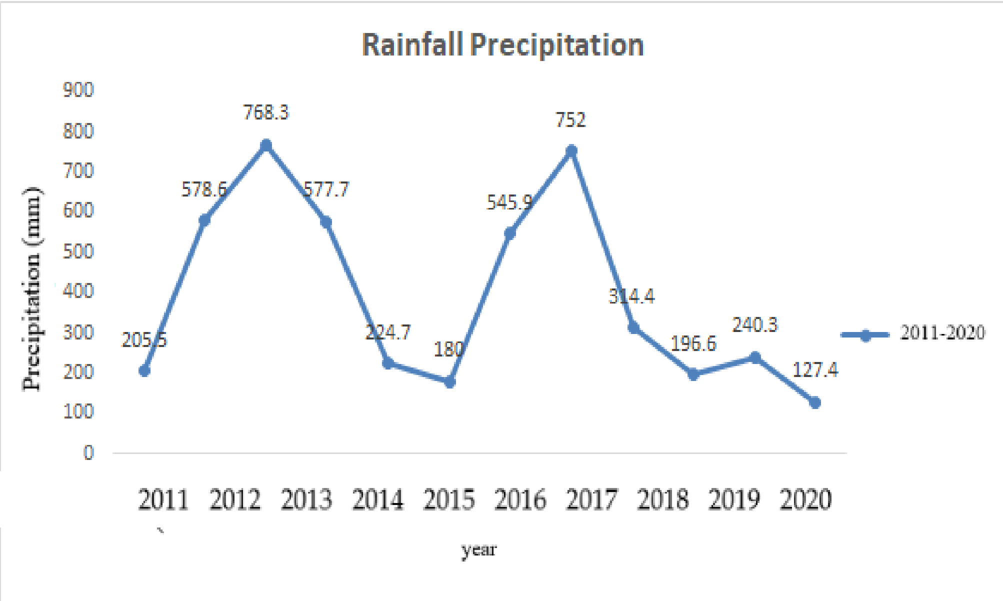

Figure 3.2: The rainfall precipitation in the Peshawar basin from 2011-2020.

Total precipitation is equal to 4,704 mm

3.2 Map of Peshawar Basin

It is surrounded by mountains on the west and southwest banks of the Peshawar Basin. The central and eastern parts of the Peshawar Basin are mainly flat. As shown in Figure 3.3, the gentle slopes from south to west and north to east can be seen. The map in (Fig 3.3a &b) shows the map of Peshawar Basin with an area of 7,176 km^2 & 7,161 km^2 (Fig 3.3a &b).

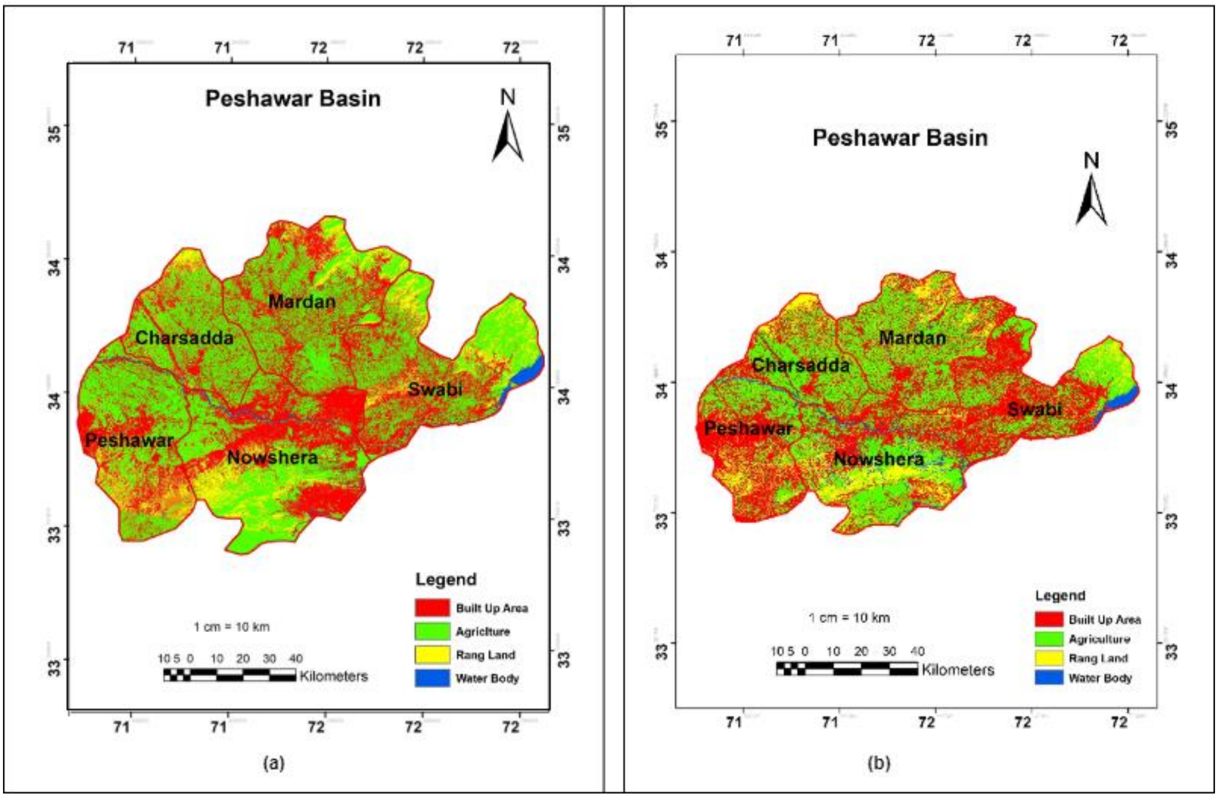

Figure 3.3: (a) Map of Peshawar Basin from 2010 with study area. (b) Map of Peshawar Basin 2020 with study area. The details of this figure show in table 3.2

It can be seen in (Fig 3.3a &b) that a large portion of the total area of the regions is agricultural land. The settled area is comparatively less, and this factor will help recharge in the Peshawar basin.

Table 3.1: Classes delineated based on supervised classification (Zahra et al., 2016)

Sr. no.	Class name	Description
1	Agricultural area	Crop fields and fallow lands
2	Built-up area	Residential, commercial, industrial, transportation, roads,
3	Rang Land	Mixed forest lands
4	Waterbody	River, open water, lakes, ponds, and reservoirs

Table 3.2: The results of LULC Show the Built-Up Areas, Agriculture, Rang Land, and Water Body, and the total area of Peshawar Basin in both 7.176 km^2.

Land use and land cover categories	**2010**		**2020**		**2010–2020**
	Area(km^2)	Area (%)	Area (km^2)	Area (%)	Changed area (%)
Waterbody	116.494	1.623	93.576	1.306	-0.317
Built up area	2,943.865	41.023	4,117.805	57.503	+16.48
Rang Land	980.095	13.657	573.190	8.004	-8.004
Agricultural area	3,132.889	43.657	2,376.929	33.193	-10.464
Total area	7,176		7161		

3.2.1 Total Area of Peshawar Basin

The Peshawar Basin is located in the heart of Khyber Pakhtunkhwa Province, Pakistan. The valley covers an area of 7,176 square kilometers and flows through the Kabul River. The average height is 345 meters (1,132 feet). Peshawar, Mardan, Swabi, Charsadda and Nowshera are the five most populous cities in the valley. As shown in Figures 3.4 and 3.5, the Peshawar Basin has a total area of 7,176 square kilometers, including 5 districts.: Peshawar, Charsadda, Mardan, Swabi, and Nowshera. Nowshera District is on the top place having 18534 km^2 area and Swabi and Mardan are nearly equal in an area having 1540 km^2 and 1558 km^2, respectively. On the other hand, Nowshera has an area of 1270 km^2, and finally, Charsadda is the smallest, having only 947 km^2.

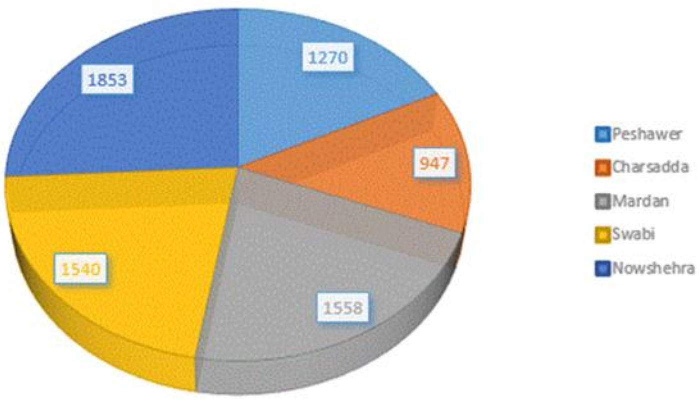

Figure 3.4: Total of Peshawar basin is 7,176 km^2 including five districts: Peshawar having 1,270 km^2, Charsadda 947 km^2, Mardan 1,558 km^2, Swabi 1,540 km^2, and Nowshera 1,853 km^2.

According to the settlement estimation of Peshawar basin with its five districts as shown in (Figure 3.4) Peshawar district is on the top having more than one-fourth of weightage. Mardan is in second place, having 22% of the total settlement area. The remaining three districts; Nowshera, Swabi and Charsadda have approximately the same percentages.

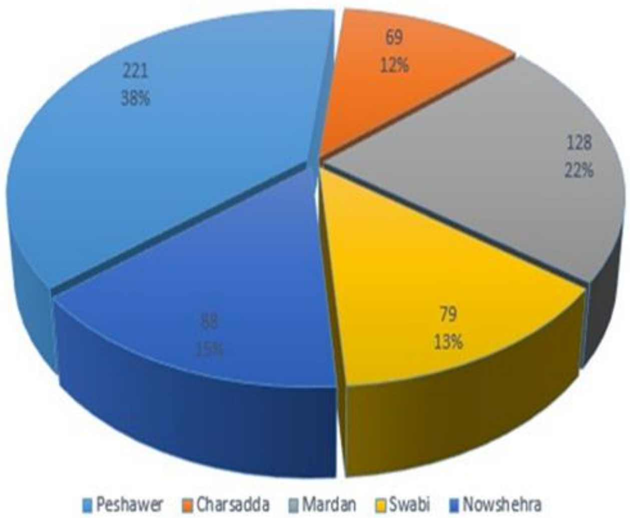

Figure 3.5:shown the Peshawar basin with its five districts such is Peshawar district is on the top has more than one-fourth weightage. Mardan is in second place having 22% of the total settlement area. The remaining three districts; Nowshera, Swabi.

(Figure 3.6) shows that the total volume of running water body of settlement areas in Peshawar basin is 13.9 and 19.4 cubic per km it decreases from left to right due to cut.

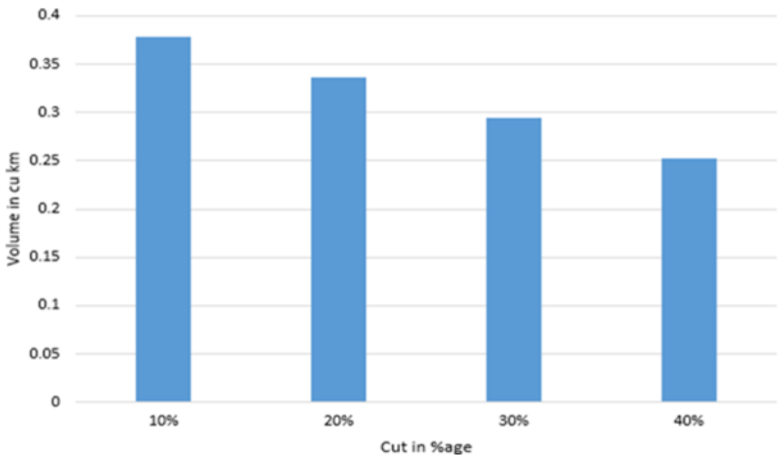

Figure 3.6:Total volume of running water body of settlement areas in Peshawar basin.

3.2.2 Map of District Charsadda

The area of district Charsadda is 947 km^2. The map of the Charsadda region is shown in (Figure 3.7 a & b). It can be seen in (Figure 3.7 a & b). that a large portion of the total area of the Charsadda region is agricultural land. The settled area is comparatively less, and this factor help recharge in recharging the Peshawar basin.

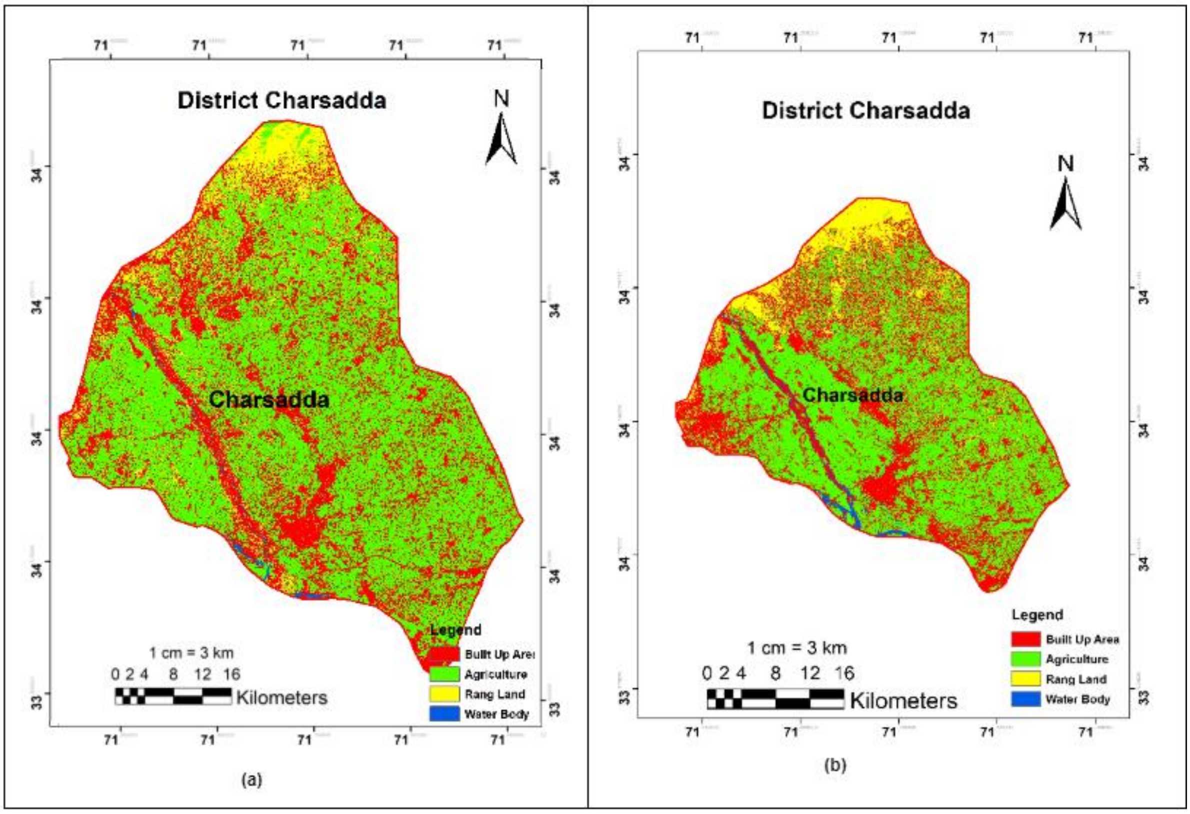

Figure 3.7: (a) Map of district Charsadda (2010) (b) Map of district Charsadda (2020).The details of this figure show in table 3.3

Table 3.3: The results of LULC Show the Built-Up Areas, Agriculture, Rang Land, and Water Body, and total area of district Charsadda in sq.km and also percentage.

Land use and land cover categories	2010		2020		2010–2020
	Area (km^2)	Area (%)	Area(Km^2)	Area (%)	Changed area (%)
Waterbody	6.799	0.682	3.845	0.386	-0.296
Built up area	335.412	33.675	445.078	44.686	+11.011
Rang Land	88.349	8.870	55.047	5.526	-5.526
Agricultural area	566.198	56.847	492.794	49.472	-7.375
Total area	996		996		

(Figure 3.8) shows that the total volume of running water body of settlement areas in Peshawar basin is 0.419 cubic per km.

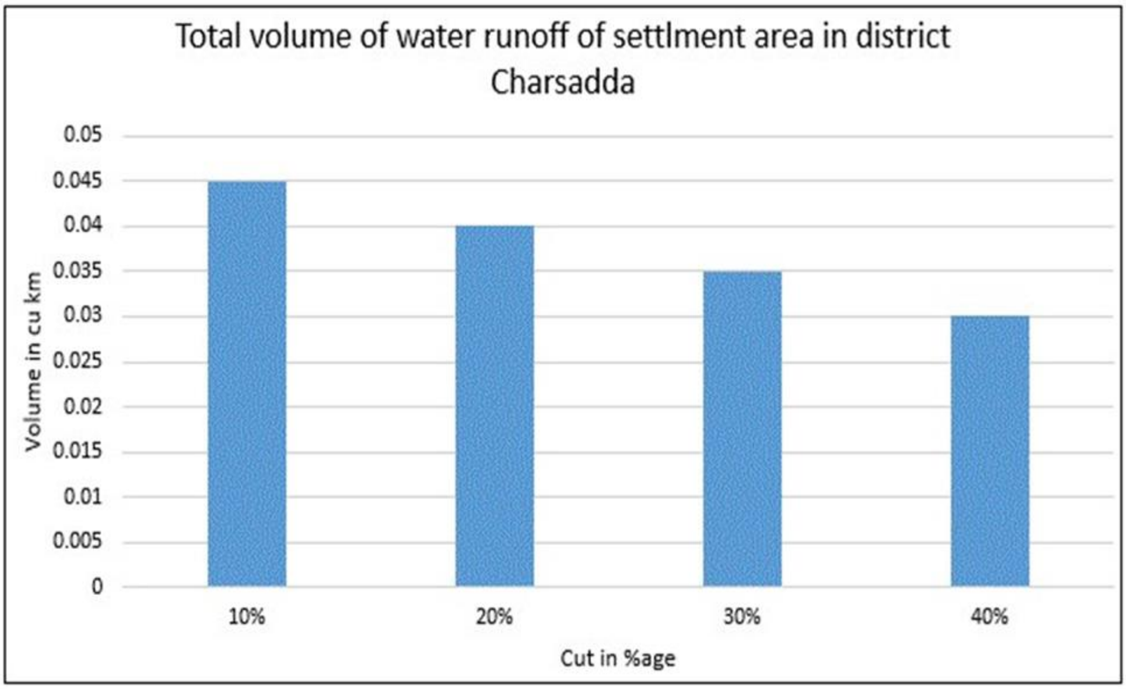

Figure 3.8:Total volume of running water of settlement area of district Charsadda

3.2.3 Map of District Peshawar

The map of the Peshawar region is shown in (Figure 3.9 a & b). The area of district Peshawar is 1,257 km^2. It can be seen in (Figure 3.9 a & b). that a large portion of the total area of the Peshawar region is also agricultural land. The settled area is comparatively less, and this factor will help recharge the Peshawar basin

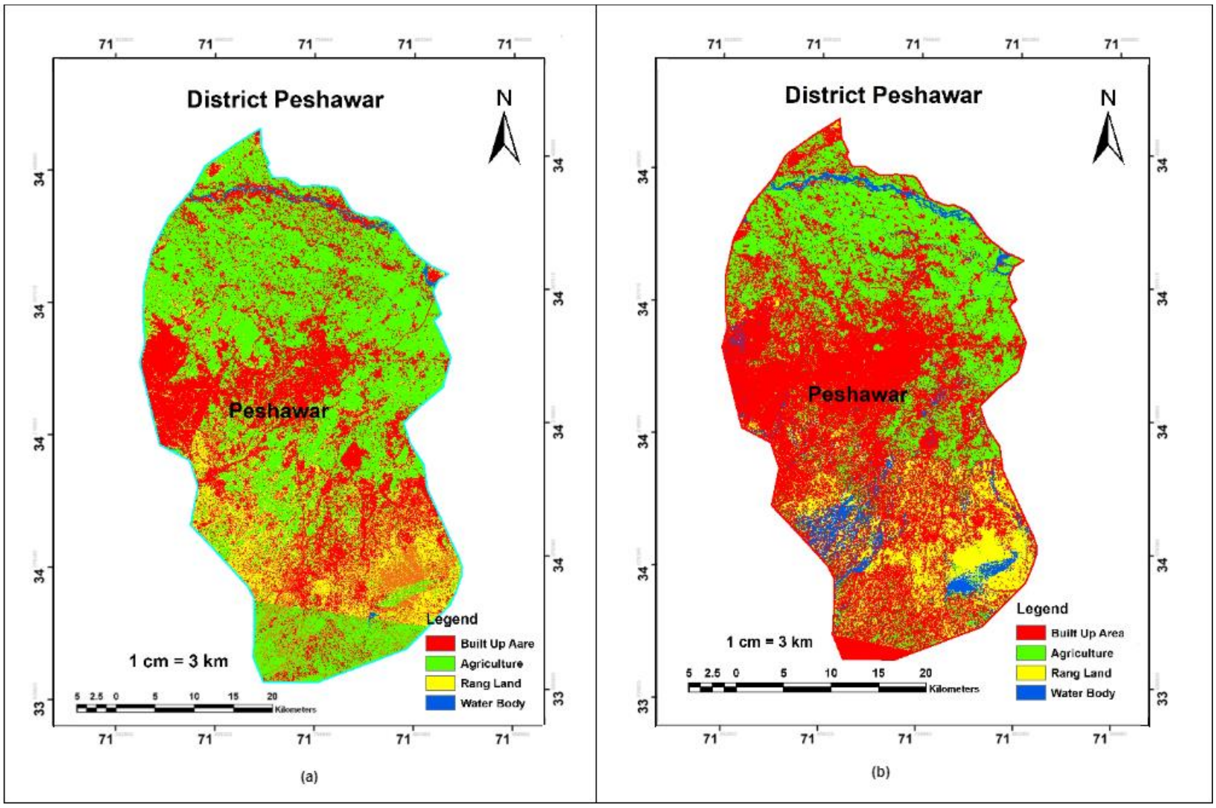

Figure 3.9: (a) Map of district Peshawar (2010) (b) Map of district Peshawar (2020). The details of this figure show in the table 3.4

Table 3.4: The results of LULC Show the Built-Up Areas, Agriculture, Rang Land, and Water Body, and total area of district Peshawar in 1257 km^2 and also the percentage

Land use and land cover categories	**2010**		**2020**		**2010–2020**
	Area (km^2)	Area (%)	Area(km^2)	Area (%)	Changed area (%)
Waterbody	30.455	2.422	22.607	1.798	-0.624
Built up area	687.354	56.682	902.199	71.773	+15.091
Rang Land	238.326	18.959	150.745	11.992	-6.967
Agricultural area	301.133	32.956	181.318	14.424	-18.532
Total Area	1257		1257		

(Figure 3.10) shows that the total volume of running water body of settlement area in Peshawar district is 15.007 cubic per km it decreases from left to right due to cut.

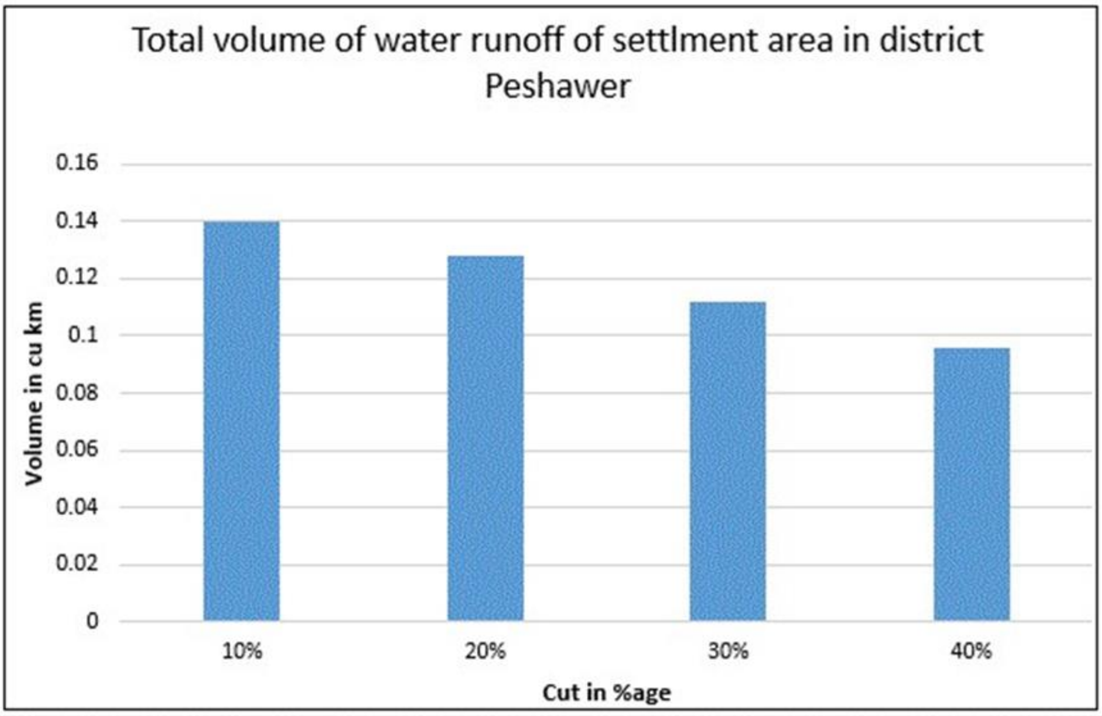

Figure 3.10:Total volume of running water of settlement area of district Peshawar

2.2.4 Map of District Mardan

The map of the Mardan region is shown in (Figure 3.11 a & b). The area of district Mardan is 1632 km^2. It can be seen in (Figure 3.11 a & b). that a large portion of the total area of the Mardan region is agricultural land. The settle area is comparatively less, and this factor will help recharge the Peshawar basin.

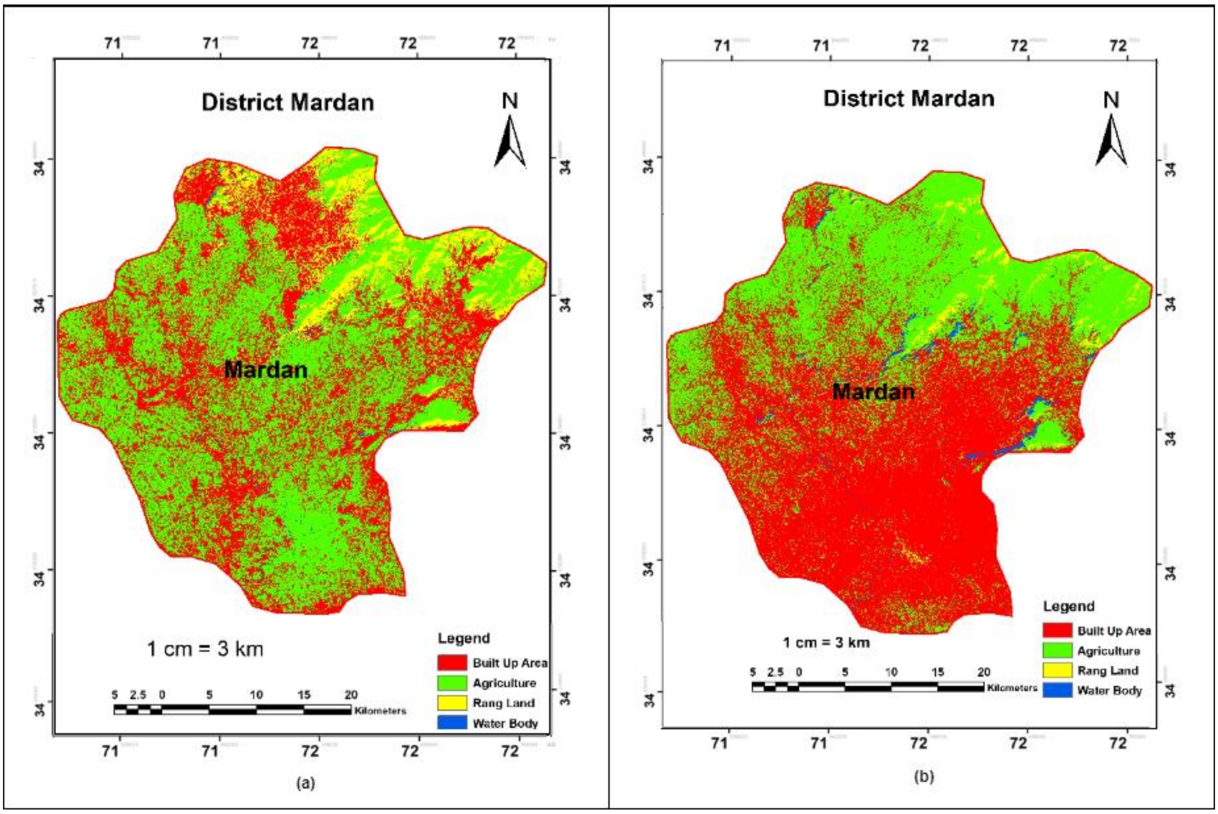

Figure 3.11: (a) Map of district Mardan (2010) (b) Map of district Mardan (2020). The details of this figure show in the table 3.5

Table 3.5: The results of LULC Show the Built-Up Areas, Agriculture, Rang Land, and Water Body, and total area of district Mardan in km^2 and also percentage.

Land use and land cover categories	**2010**		**2020**		**2010–2020**
	Area(km^2)	Area (%)	Area(km^2)	Area (%)	Changed area (%)
Waterbody	5.514	1.337	3.576	1.219	-0.118
Built up area	660.185	40.452	863.320	52.899	+12.447
Rang Land	143.229	8.776	93.570	7.733	-1.043
Agricultural area	823.500	50.459	673.008	41.238	-9.221
Total Area	1632		1632		

(Figure 3.12) shows that the total volume of running water body of settlement area in Mardan district is 14.384 cubic per km it decreases from left to right due to cut.

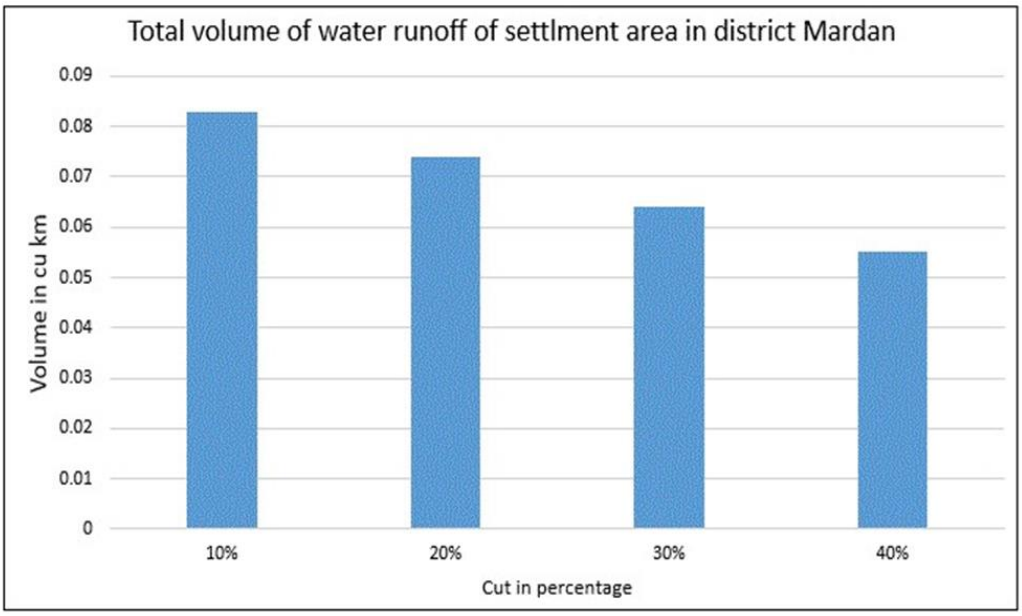

Figure 3.12:Graph of total volume of running water of settlement area of district Mardan

3.2.5 Map of District Swabi

The map of the Swabi region is shown in (Figure 3.13 a & b). The area of district Swabi is 1543 km^2. It can be seen in (Figure 3.13 a & b). that a large portion of the total area of the Swabi region is agricultural land. The settled area is comparatively less, and this factor will help recharge the Peshawar basin.

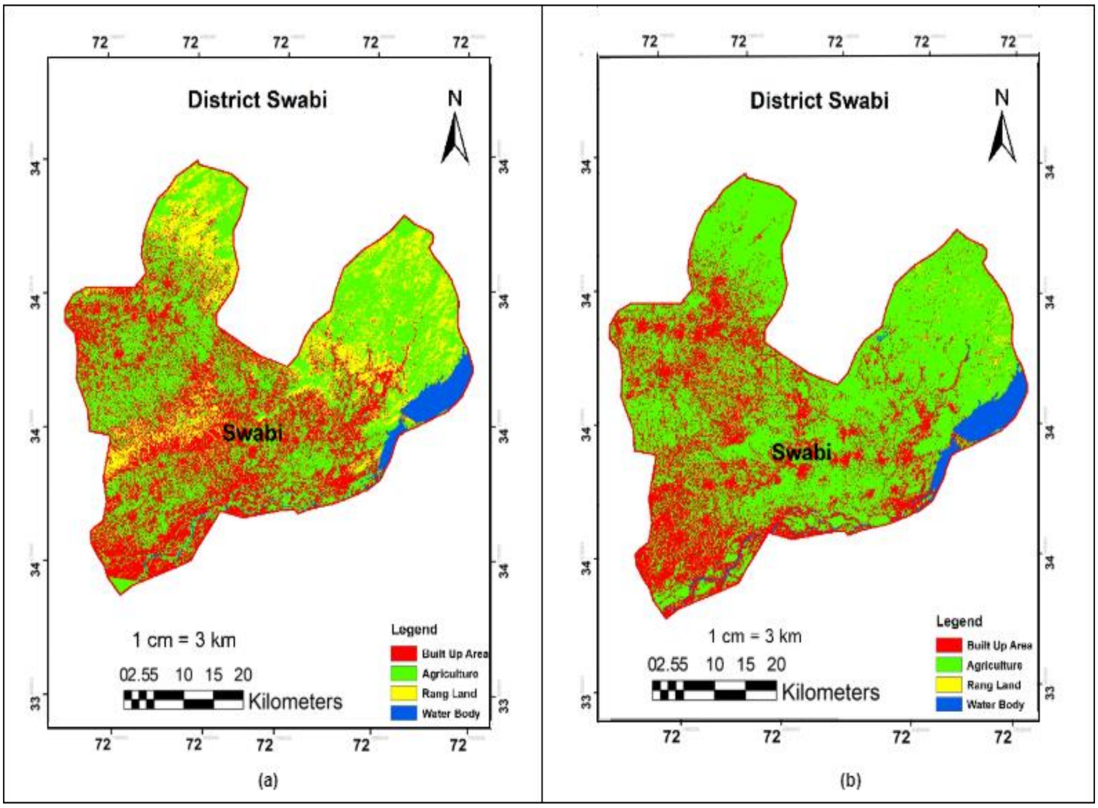

Figure 3.13: (a) Map of district Swabi (2010) (b) Map of district Swabi (2020). The details of this figure show in the table 3.6

Table 3.6: The results of LULC show the Built-Up Areas, Agriculture, Rang Land, and Water Body, and total area of district Swabi in 1,543 km^2 and also percentage.

Land use and land cover categories	2010		2020		2010–2020
	Area (km^2)	Area (%)	Area(km^2)	Area (%)	Changed area (%)
Waterbody	48.278	3.128	44.345	2.873	-0.255
Built up area	516.799	33.493	993.604	64.381	+30.888
Rang Land,	242.648	15.725	108.057	7.003	-8.722
Agricultural area	730.271	47.327	398.967	25.856	-21.471
Total Area	1,543		1,543		

(Figure 3.14) shows that the total volume of running water body of settlement area in Swabi district is 0.057 cubic per km it decreases from left to right due to cut.

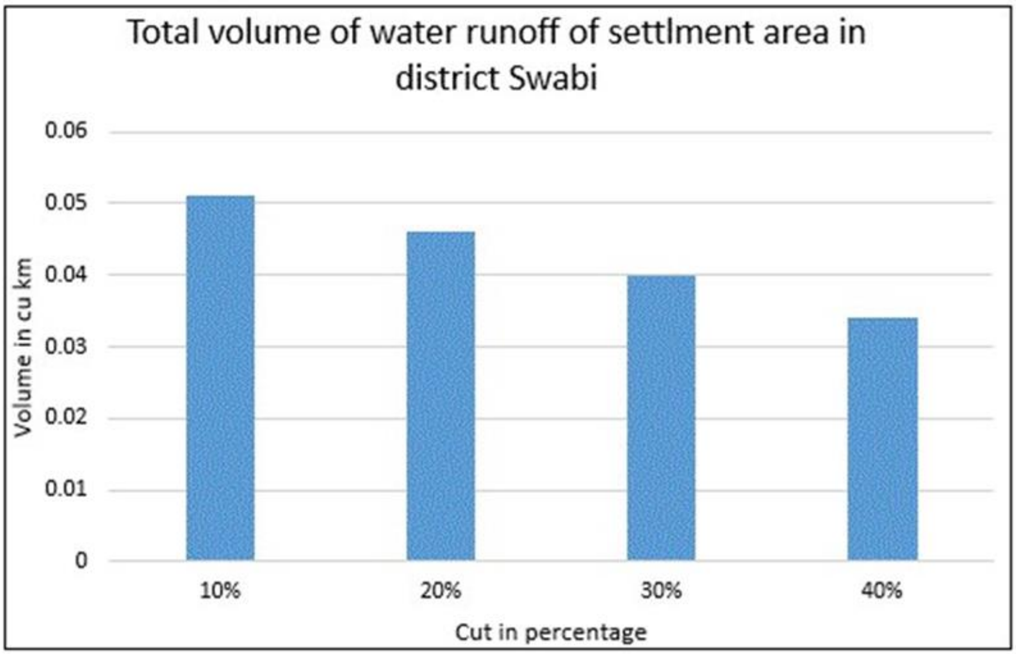

Figure 3.14: Graph of the total volume of running water of settlement area of district Swabi

3.3.6 Map of District Nowshera

The map of the Nowshera region is shown in (Figure 3.17a&b). The area of district Nowshera is 1748 km^2. It can be seen in (Figure 3.17a&b). that a large portion of the total area of the Nowshera region is agricultural land. The settled area is comparatively less, and this factor will help recharge the Peshawar basin.

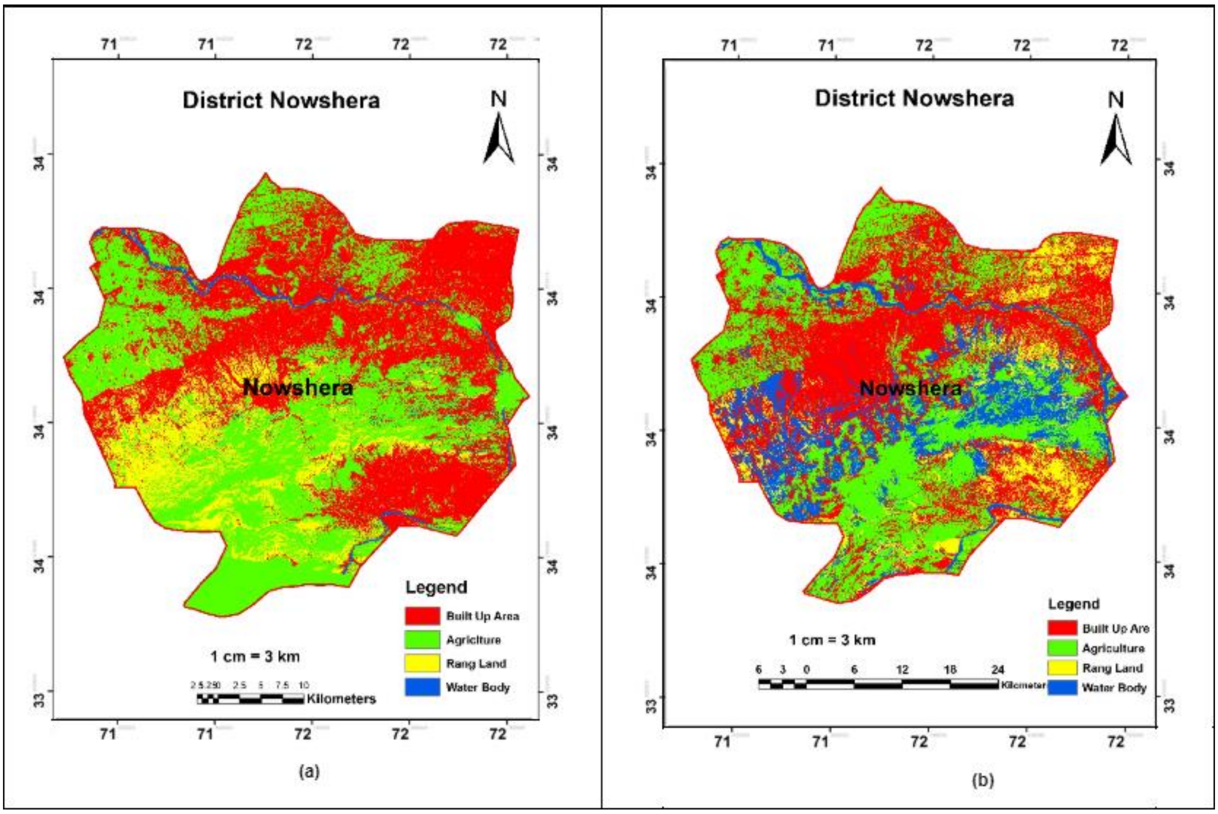

Figure 3.15: (a) Map of district Nowshera (2010) (b) Map of district Nowshera (2020). The details of this figure show in table 3.7

Table 3.7: The results of LULC Show the Built-Up Areas, Agriculture, Rang Land, and Water Body, and total area of district Nowshera in km^2 and also percentage.

Land use and land cover categories	**2010**		**2020**		**2010–2020**
	Area (Km^2)	Area (%)	Area(Km^2)	Area (%)	Changed area (%)
Waterbody	25.448	1.455	19.203	1.104	-0.351
Built up area	744.115	42.569	931.604	53.295	+10.726
Rang Land	267.543	15.305	165.348	9.459	-5.846
Agricultural area	712.287	40.748	631.205	36.110	-4.638
Total Area	1748		1748		

(Figure 3.16) shows that the total volume of running water body of settlement area in Nowshera district is 15.821 cubic per km it decreases from left to right due to cut.

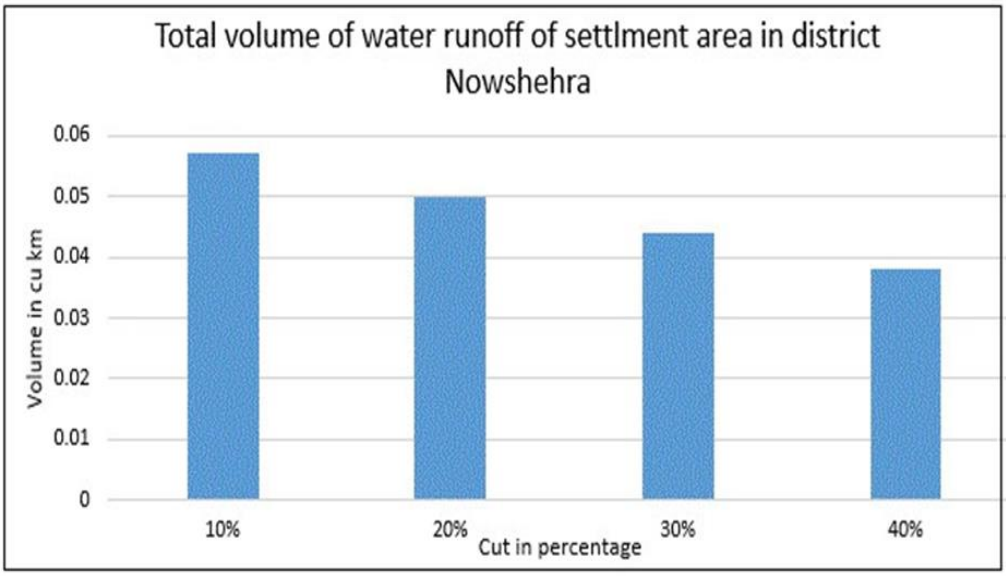

Figure 3.16: Graph of the total volume of running water of settlement area of district Nowshera.

3.3 Volume of running waterbody:

The output data from the GIS modeling were then analyzed by using specific software tools and finally, the results for the volume of water in the study area were presented. The volume of running water can be calculated using equation (1). The major steps are detailed below:

The volume of water = settlement land area * rainfall precipitation (1)

- The Settlement area of the Peshawar basin from 2000-2010 is 2944 km^2.
- The Settlement area of the Peshawar basin from 2010-2020 is 4,118 km^2.
- The total sum of rainfall precipitation of the Peshawar basin from (2000 – 2020) is 10282 mm.

2.3.1 Applying cut

Applying cut means that some water is infiltrated from running water. In the current study, we have applied cuts because we have data of four different areas i.e. Rangeland, , Built-Up Areas and Agriculture. All these three areas are the main causes for the excessive loss of water, so for this reason, we applied cuts to calculate the possible volume of running water. Therefore, in this study, we apply the following cuts:

Cut for 2000-2020

- 10% cut leaves 1.609 cubics per km of running water.
- 20% cut leaves 0.804 cubics per km of running water.
- 30% cut leaves 0.536 cubics per km of running water.
- 40% cut leaves 0.402 cubics per km of running water.

Similarly, the total volume of running water of Peshawar basin without a cut from 2000-2020 is 20.9 cubic km

CONCLUSIONS

Outcomes generated from GIS models are beneficial for evaluating and assessing the environmental impact of water flow and resources. It provides the basics for the decision process relevant to the turbulences and urgency within environmental management. GIS applications make it possible to estimate the total potential of running underground water by determining the appropriate locations. The application of GIS techniques provides consistent, precise, and up-to-date data records on land underground water and running rainfall water. The rainfall precipitation data is taken from the Regional Meteorological Department of Peshawar from Jan (2000 to 2020). The total volume of water was calculated by using the GIS for the selected locations in the current study area. The output data from the GIS modeling were then analyzed by using specific software tools and finally, the results for the volume of water in the study area were presented. The volume of running water can be calculated using equation (1):

The volume of water = settlement land area * rainfall precipitation (1)

were,

- The Settlement area of the Peshawar basin from 2000-2010 is 2944 km2.
- The Settlement area of the Peshawar basin from 2010-2020 is 4,118 km2.
- The total sum of rainfall precipitation of the Peshawar basin from (2000 – 2020) is 9,444 mm.

Based on the modeling results, the total area of the Peshawar basin is 7,174.360sq. Km. After that, using the rainfall data, the total rainfall precipitation data of Peshawar Basin was evaluated to be 10282 mm. mm with the help of these two values (area and rainfall precipitation), the total volume of running water in the Peshawar basin was calculated. The total volume of running water past 20 years in the Peshawar basin was 72611484 cubic per km. By applying cuts at 10%, 20%, 30% and 40 %, the volume of water runoff of settlement area was calculated to be 0.419 cubic km. The map of the Peshawar basin and the various districts shows that a large portion of the total area is Population/Built-up area. The settled area is comparatively large.

Results show that, from 2000 to 2020, there is a significant increase of 16.48% in urbanization and a decrease of 10.46% in vegetation. These results can be useful for future planning and development.

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